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THE FORMS OF ANTAGONISM CURVES AS AFFECTED BY CONCENTRATION

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(WITH THREE FIGURES)

A study of the literature shows that the effect of concentration on the form of the antagonism curve is not fully appreciated. The alterations in the form of the curve are very marked when solutions are diluted to one-half strength. The writer has found this to be the case with antagonism curves of different types obtained by using a great variety of solutions. The purpose of this paper is not to give the results of these experiments, but merely to state some general principles in the hope that they may be of use to those who have occasion to make quantitative studies on antagonism.

For this purpose curves have been prepared which are diagrammatic composites of the curves obtained by the use of several pairs of salts; these composite curves are shown in fig. 1. For the sake of simplicity they are represented as having been obtained by the use of one pair of salts, which are designated as *A* and *B*. The curve *CDE*, therefore, represents diagrammatically the growth of roots in mixtures of equally toxic solutions of two salts, *A* and *B*. The abscissas represent molecular proportions; thus the point *G* represents a mixture in which the dissolved molecules are 75 per cent *A* and 25 per cent *B*; the point *H* a mixture in which the dissolved molecules are 50 per cent *A* and 50 per cent *B*. The ordinates represent the growth of roots in the various mixtures.

The antagonism at any point is the total growth minus the growth which would have taken place if no antagonism existed.¹ This antagonism is best expressed as percentage of the growth which would have taken place in the absence of antagonism. Hence the antagonism at the point *G* is expressed as $\frac{FD-FG}{FG} \times 100$.

¹ This latter amount of growth is called the additive effect and is expressed by the horizontal dotted line *CE*. Cf. BOT. GAZ. 58:178. 1914.

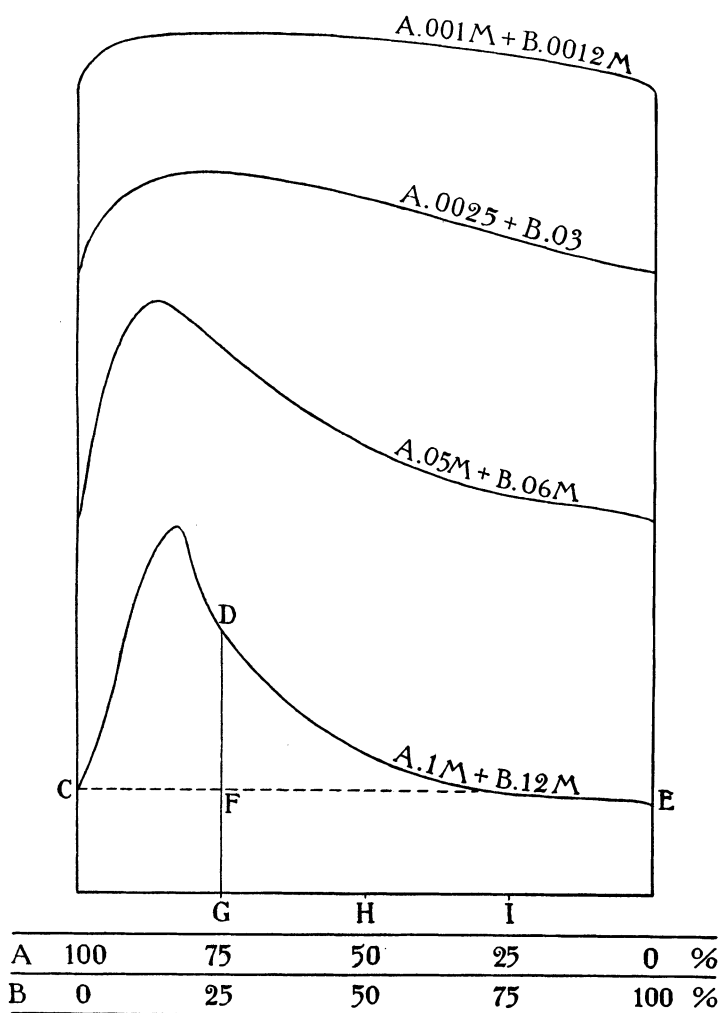


FIG. 1.—Effect of dilution on the forms of antagonism curves: the ordinates represent the growth of roots in solutions, the composition of which is represented by the abscissas; for example, on the curve *CDE* the ordinate at *G* represents growth in a mixture of *A* 0.1 M and *B* 0.12 M in such proportions that 75 per cent of the dissolved molecules are *A* and 25 per cent are *B*; on the curve which lies immediately above *CDE* the ordinate at *G* represents growth in a mixture of *A* 0.05 M and *B* 0.06 M in such proportions that 75 per cent of the dissolved molecules are *A* and 25 per cent are *B*.

The figure shows in a diagrammatic way the effect of dilution on the form of an antagonism curve. The lowest curve *CDE* shows the effect on growth of various mixtures of two equally toxic solutions $A\ 0.1\ M + B\ 0.12\ M$. The next curve shows the form of the antagonism curve when all of these mixtures were diluted by the addition of an equal volume of water ($A\ 0.05\ M + B\ 0.06\ M$). The next curve was produced by growing plants in mixtures of $A\ 0.0025\ M + B\ 0.03\ M$. The topmost curve was obtained with mixtures of $A\ 0.001\ M + B\ 0.0012\ M$.

The pairs of pure solutions were in each case equally toxic, as is shown by the fact that the two ordinates at the ends of each curve are equal in height.

It will be observed that as the solutions become more dilute, the antagonism curve becomes flatter, and it is evident that at still greater dilutions it must tend to become a horizontal straight line.

In order to give a complete description of the changes in the antagonism curve as dilution increases, it is necessary to construct a solid model. This might have as its base a triangular diagram as described in a previous paper.² The apices of the triangle would in that case represent *A*, *B*, and H_2O .

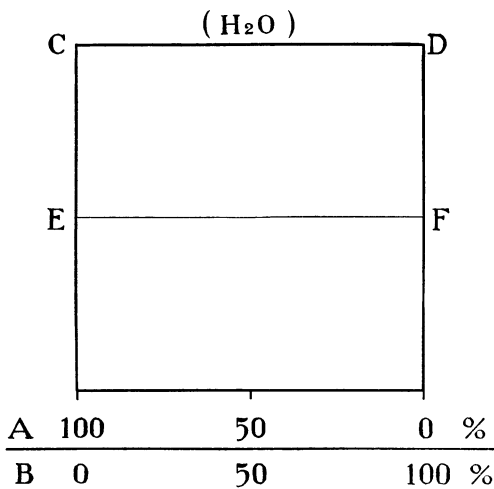


FIG. 2.—Diagram representing the composition of solutions (this serves as the base of the solid model shown in fig. 3): the lowest line represents various mixtures of solutions of two salts, *A* and *B*; the line *EF* represents the same mixtures diluted with equal volume of water; any line drawn parallel to *EF* will express the same mixtures diluted to a degree corresponding to the position of the line, the nearer it approaches to *CD* the greater the dilution; on the line *CD* all points represent distilled water.

² BOT. GAZ. 58:178. 1914.

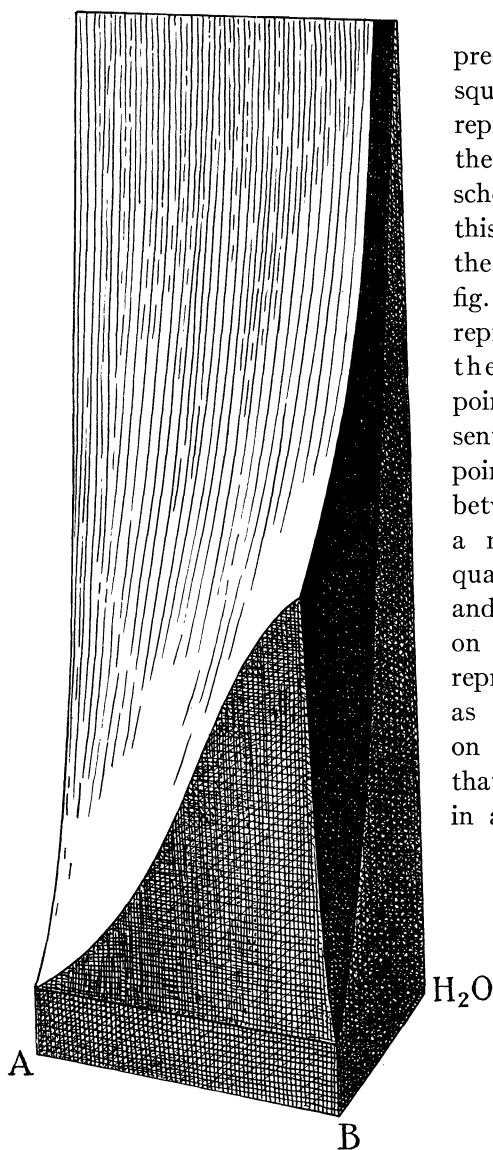


FIG. 3.—A solid model which gives a complete description of the changes produced in the form of the antagonism curve by altering the concentrations of the solutions.

It is more suitable for our present purpose to employ a square as the base and to represent the composition of the solutions according to the scheme shown in fig. 2. In this figure the abscissas have the same significance as in fig. 1, while the ordinates represent various dilutions of the mixtures. Thus all points on the line *CD* represent distilled water, while a point such as *E*, halfway between *A* and *C*, represents a mixture containing equal quantities of distilled water and of *A* 0.1 M. The points on the line *EF*, therefore, represent the same mixtures as the corresponding points on the lowest line, except that the concentrations are in all cases just one-half as

great as those represented on the base line.

It is evident that the growth in any concentration may be expressed by erecting at the proper point a line perpendicular to the plane of the paper. In this way we may obtain

a solid model which gives a complete description of the changes in growth produced

by diluting the various mixtures. Such a model is shown in fig. 3.

It may be desirable to add something concerning the comparative amount of growth in distilled water and in balanced solutions. When dilute solutions are employed, the maximum growth obtained in a fully balanced solution may be greater than that in distilled water, owing to the nutrient action of the solution. But when strong solutions are employed, this is not the case, for the osmotic pressure of the strong balanced solution will inhibit growth.

In general, growth in strong solutions furnishes a much more satisfactory criterion of antagonism than growth in weak solutions. The inhibition of growth due to the osmotic pressure of the strong solutions does not noticeably affect the form of the antagonism curve, since it makes itself felt in the pure solutions to about the same degree as in the mixtures. When we employ the method of mixing equally toxic solutions, the osmotic disturbances are compensated in a manner which has been previously discussed.³

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³ BOT. GAZ. 58:178. 1914.